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UNITED STATES DEPARTMENT OF INTERIOR
GEOLOGICAL SURVEY

Seismic Survey of Lake Baikal, Siberia: **Operational Technical Summary for the RV Balkash and RV Titov**

15 August to 30 September 1992

by
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U.S. Geological Survey Open File Report ~~OF-93-XX~~ OF-92-693

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Woods Hole, Mass.

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Not available

INTRODUCTION

During the months of August and September, a multichannel seismic reflection(MCS) and a seismic-refraction survey of Lake Baikal using ocean bottom seismometers(OBS) was undertaken as a joint research project by U.S. and Russian scientists. Over 1800 km of MCS data and over 500 km of OBS data were acquired during this program. This report will summarize the operational and logistical issues required for both the MCS and OBS operations. The MCS work also included on board seismic processing facilities for quality control and demultiplexing of seismic data during the cruise. This study was carried out on two research vessels, the RV BALKASH for overall MCS work and the RV TITOV for OBS deployments. Most information will focus on the equipment used on this expedition and the co-operative agreements reached on the operational issues and equipment selection. Working on Lake Baikal, Siberia, which is 13 time zones from the East coast, provided some interesting problems for logistics and co-ordination between USGS and our Russian colleagues. Approximately three years of planning went into preparation for this expedition including equipment design, fabrication, acquisition, etc.. Special export documents had to be prepared due to the sensitivity of our sophisticated electronics, which ranged from the GPS navigation instruments to multi-user computer stations used for data processing. Having worked on Lake Baikal during two previous expeditions, it was very obvious that many changes have taken place during that time. However, logistically speaking there will always be major problems with equipment handling within Russia. To anyone who plans to work on Lake Baikal, please plan years in advance if possible. **"Forewarned is Forearmed".**

PRE-CRUISE PREPARATION

Pre-cruise preparation consisted of three phases:

(1) Division of equipment responsibilities U.S./Russia
(2) Equipment acquisition USGS/Russian
(3) Equipment calibration/shipment

Divisions of equipment responsibilities were decided at a November meeting in Moscow and Irkutsk with Dave Nichols, U.S.Geological Survey, Dr. Chris Scholz, Duke University, Alexander Golmshtok, Southern Branch of the Institute of Oceanology, and Lyosha Akentiev, Southern Branch of the Institute of Oceanology attending. During these meetings it was decided that the U.S. Geological survey would provide all the data acquisition, data processing, and navigational systems. During these discussions, it became clear that U.S. Geological Survey (USGS) could not provide the air gun array with firing and control circuitry as the cost of leasing this type of system from industry is prohibitive. However, we could provide a large high pressure air compressor leased from the Price Compressor Co., Houston Texas. Our Russian colleagues provided two air gun arrays, one 10-gun clustered array and one 2-gun array which included the firing and control circuitry for both arrays. The Russians also provided a 96 trace streamer with azimuth, depth, and leveling capabilities, and a magnetometer. All OBS equipment was provided by U.S.Geological Survey, Woods Hole, MA.

Equipment acquisition was a major complication for both sides prior to the expedition. Equipment for the multi-channel portion of the expedition had to be leased from industry or borrowed from our sister Branch of Pacific Marine Geology (PMG). The shipping date to Siberia was April 15th 1992, and all the equipment to be shipped finally arrived by the first week in April. The Russians had hard currency transfer problems up until very late in the program which threatened to cancel the expedition altogether. Because of the shear volume and weight of the equipment, USGS purchased three standard IOS 20 ft. shipping containers for shipment to Russia. All containers arrived in Siberia by early July with the equipment intact . Two overseas carriers "Mayflower International and Orion Marine" routed equipment via New York/Nahodka/Irkutsk/Lystvianca. Once on the Russian coast, the containers traveled via rail to Irkutsk. Having exported scientific equipment to Siberia for the past three years using many avenues and methods, it is advisable not to ship by air, if time permits. Shipping by air is cost prohibitive and dangerous for the equipment.

Equipment preparation was completed in a timely fashion. Two mechanical engineers traveled to Houston for instruction on the high pressure air compressor. The DFS V acquisition and recording instrumentation was prepared and reconfigured at PMG by Bill Robinson. Navigational instrumentation and all OBS equipment were prepared in house at USGS Woods Hole.

MCS Field Systems U.S.Geological Survey/Institute of Oceanology

The following MCS Field systems were provided by USGS and utilized on board RV Balkash (the MCS Vessel):

A. Acquisition and recording systems
   1. Texas Instruments DFS V Seg B acquisition system , including 2 analog modules - 96 trace, 2 1600 bpi, 9 track tape transports, 4 ms sample rate, and 5.3 hz to 64 hz recording filters.
   2. EG&G 48 trace electrostatic plotter.
   3. EPC 4800 3 trace plotter.
   4. Teledyne model 300 low resolution amplifiers.
   5. 3 BNC timer delay boxes.
   6. Tektronix model 504 storage scope.

B. Navigation System
   1. Ashtech GPS Receiver Model XII with nongeodetic antenna
   2. IBM-PC AT logging computer
   3. Mod Graph (PC compatible) logging computer

C. Seismic Processing Systems
   1. Mass Comp MC 5400 computer
   2. Mass Comp MC 6600 computer

D. Heavy Machinery and other
   1. Price high pressure air compressor Model A-35 AC (175 scfm)
   2. Onan 6.8kva air-cooled diesel generator
   3. Onan 7.5 kva water-cooled diesel generator
   4. Exide Electronics 3.5 kva uninterruptible power supply (UPS)
   5. Exide Electronics 6.5 kva uninterruptible power supply (UPS)
   6. Due to experience in two other field expeditions to Lake Baikal, the U.S.Geological survey provided substantial food supplements for both ships during the expedition.

The following field systems were provided by the Southern Branch of the Institute of Oceanology, Gelendzhik, Russia and utilized on board RV Balkash (the MCS Vessel):

A. Seismic acquisition and recording systems

1. 96 trace digital acquisition and recording system, manufactured in-house, was not used due to excessive electrical noise introduced into DFS V by custom patch panel.
2. IBM PC based digital plot of near trace. Software was developed in house by the Southern Branch for this purpose.
3. 96 trace patch panel for DFS V recording system
4. IBM PC 386 for storage of file mark, streamer depth, streamer azimuth and operation of the streamer leveling system.
5. 96 trace streamer (Holland manufacture, German jacket, and Russian assembly) with the following characteristics: sensitivity = 40 microvolts/bar, 25 meter groups/31 phones per group, 100 meter sections/4 groups per section, 25 meter center group to center group, and total length = 2800 meters with stretch sections.
6. "Neftegeophyspribor" Russian manufactured PC based streamer positioning control and monitoring system with 8 cable levelers(birds),8 depth points and 4 compass units providing azimuth. Birds and depth information recorded from channel locations 1, 17, 33, 41, 49, 65, 81, and 96. Azimuth information recorded from channel locations 9, 41, 73, 89.
7. "Actpa" Russian manufactured PC based air gun control and fire circuitry for 10 gun array.
8. Proton precession magnetometer (MPM5M) torodial sensor using Oktan or similar hydrocarbon fluid designed and built by Dr. Ivan I.Belyaev at the Institute of Oceanology, Moscow. This unit has a sensitivity = 0.1nT, a sample rate = 10 seconds, and data is digitally recorded on IBM-PC-AT compatible computer.

B. Heavy Machinery and other

9. 2 Junkers "opposed piston"75 standard cubic feet per minute (scfm) high pressure air compressors.
10. 10 air gun clustered array (Russian Manufactured).
11. 2 air gun array for OBS lines (Russian Manufactured).
12. Special firing circuitry for the issuing of shot instant was designed and redesigned many times during the expedition due to the different needs of the two separate gun arrays.

OBS Field Systems U.S. Geological Survey

The following OBS equipment was provided by USGS and utilized on board the RV TITOV (the OBS Vessel):

1. 4 - Large sphere OBS's rated to a depth of 5,000 meters.
2. 4 - Small sphere OBS's rated to a depth of 500 meters.
3. Dell 386 PC computer system with 2.2 gigabyte hard disk and an Exabyte 8200, 8mm tape drive.
4. Austron GPS satellite clock.
5. Nicolet 320 storage oscilloscope.
6. Phillips frequency counter.
7. Benthos 210 acoustic release system.
8. 40 OBS anchors.
9. 3200 "D" batteries.

OPERATIONAL CONFIGURATIONS

1. Seismic Sources:

The main energy source for most of the MCS profiling was a tuned airgun array containing 10 guns in three clusters. Total volume of the array was 1665 cu.in (27.3 liters).The air guns were of the sleeve type built in Russia and

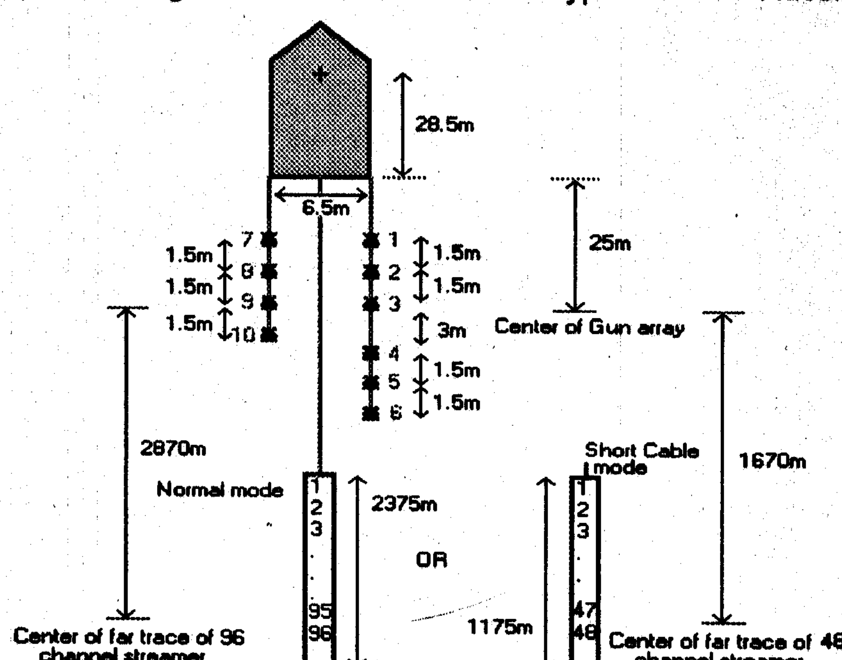

Figure 1. MCS Tow Configuration - R/V Balkash

divided into three clusters towed from port and starboard strings. Appendix 1 shows sleeve gun schematic and Figure 1 outlines the MCS tow configuration. Shot spacing for MCS profiling used a time interval of between 23-25 seconds depending on ships speed over ground. Data was collected at 24 fold for most of the operation. However, there were several short lines in tight turn areas which required shortening the streamer to 48 traces. This reduced the data to 6 fold. The individual gun signatures with their frequency content are illustrated in Appendix 2. Appendix 3 shows the three individual cluster signatures and frequency content, and Appendix 4 shows the combined 3 clustered array signature and frequency content. Notice the cancellation of the bubble pulse when the guns are configured in this clustered tow arrangement.

The energy source for the seismic-refraction profiling was a non-tuned array of two 3660 cu.in (60 liter) air guns. These guns were fired at two minute intervals during the OBS lines. With all three compressors operating, the total pressure varied from 1600psi to 1700psi instead of the desired 2000psi. Appendix 5 shows the 60 liter air gun schematic. This gun was designed by I.Palichev, L.Akientev, and N.Badikov.

2. Seismic Acquisition Recording Systems:

The 96 trace streamer was supplied by the Russian's. Except for a few very short lines, which used 48 trace, the streamer was 96 channels comprised of 24, 100 meter sections, with 4 channels per section. The total length of the streamer with stretch sections is 2800 meters. Figure 2 shows the towing configuration of the streamer with the levelers and attitude sensors. There are 8 cable levelers (birds), 8 depth points and 4 compass units providing azimuth.

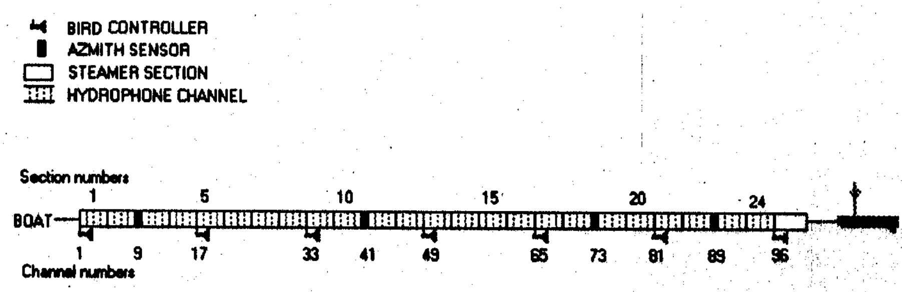

Figure 2. 96 Trace Streamer Configuration

The computer system would log and illustrate the attitude information and provide all the commands to keep the streamer at a constant, even depth.

During the November, 1991 meetings it was decided that, if possible, two systems would be used to log data from the 96 trace streamer (The Russian in house 96 trace digital system and the U.S. 96 trace DFSV system). This would enable both groups of scientists to have a complete data set. . Both systems used 9-track recording media, but the Russian system records at 800 bits per inch(bpi) while the DFSV records at 1600bpi. Two separate interface schemes were discussed so that electrical interference from the streamer interface could be kept at a minimum.

Figure 3 illustrates the Russian System signal flow and coupling schematic. The Russian acquisition system is based on a charge-coupled streamer configuration with 1.5vdc applied to each individual channel. The USGS acquisition system could not be effectively interfaced with a charged-coupled streamer, so any connections made with the USGS system required using the transformer used in the Russian amplifier section. Two options were proposed to attempt using both systems in parallel.

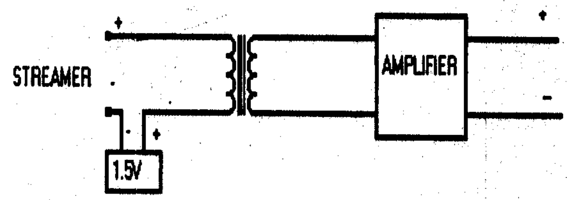

Figure 3. Block Diagram of Russian Connection of Streamer to Recording System

Figure 4 illustrates the first method. The advantages of using this method are that it is simple to connect, and it isolates the DFSV system from the charged-coupled streamer by using the transformer built into the Russian acquisition system. The disadvantages of this method is the input requires a differential input to minimize any noise that will be generated by both recording systems, and the impedance of the amplifiers used in both systems must be similar to minimize signal loss to the other system. The input impedance of the DFSV is 20,000 ohms. The input impedance of the Russian system was not known, so matching the two to minimize too much signal loss would be trial and error. The second method, illustrated in Figure 5, reduces the importance of the input impedance of the DFSV. A 24dB attenuator prevents the amplifier of the Russian system from overdriving the input of the DFSV system.

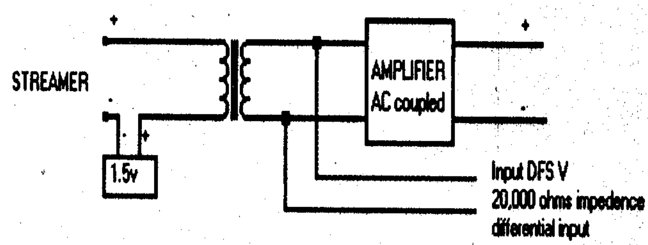

Figure 4. Method 1 for connecting the USGS DFS V to the Russian System

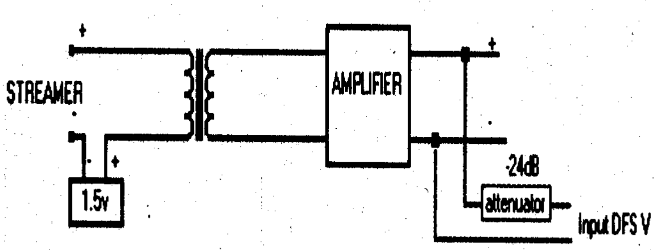

Figure 5. Method 2 for connecting the USGS DFS V to the Russian System

The second method required a differential output with low impedance to work effectively with the DFSV and, unfortunately, this was not the case. The first method was chosen, but, during actual field trials on the lake, it was discovered that with two recording systems operating simultaneously the electrical interference was just too much. The USGS DFSV system became the only recording system, as the maximum "system noise" level was the lowest, and 1600 bpi tape drives would require fewer tapes to record the data. Streamer coupling used a special junction box designed by our Russian colleagues to utilize the transformers built into the Russian acquisition system. The only noise problems resulting from this configuration were noisy switch panels.

3. System Timing for MCS

While acquiring MCS data, the R/V Balkash the air gun arrays were fired at regular time intervals rather than at a fixed distance over the bottom. Normal procedure for shooting constant depth point (CDP) seismics calls for shooting on distance rather than time, but the cost prohibitive nature of navigation hardware precluded this option. Shooting on time was accomplished by a master trigger generated from a Digital Timing Delay Generator. Constant monitoring of ship's speed-over-ground(SOG) made this procedure as accurate as possible. The master trigger would start the DFSV acquisition system, which would then issue wire blast, used for firing the air gun circuitry. This minimizes any information that may be lost as the tape drive ramps up to recording speed. The shot instant (T^0) was derived from a signal from the shot-break detectors mounted on each gun. This collective signal, once averaged in time by a PC-based gun control unit, would then be sent to the Ashtech GPS receiver. The photogrammetry input of the Ashtech would latch the satellite time on the nearest millisecond of the pulse and store the information in a log file. This information would be used in the post processing of the CDP Data. During OBS operations the same techniques were used on the Balkash for logging of the shot instant. A Teledyne shot phone was installed on the two gun array and used for the shot instant (T^0). Techniques used on the OBS vessel Titov for logging time will be discussed later in this report.

4. Power Requirements, Limitations etc.:

The power available on the two Russian vessels ranged from 380 VAC, three-phase, 50hz to 220 VAC, single phase, 50hz. Neutral was not tied to earth and could be as much as 150vac above ground. A grounding network connecting all equipment to ship's hull was constructed to alleviate any electrical hazard. After installation of the equipment onboard ship, any signal grounds on the equipment were also checked and tied to earth ground if necessary.

Previous experience with working on these vessels on Lake Baikal, determined that the best way to correct the power problems was to provide our own regulated power. An uninterruptible power supply(UPS) provided a means of converting the voltages and cleaning up any noise problems. A 6.5 kva UPS was provided for the R/V Balkash, and a 3.5kva UPS was provided for the R/V Titov. Each UPS was modified to eliminate the bypass operation In this case, the input is not the same as the output). The circuit that charges the DC battery supply is set for an input of 220 volts 50 Hertz. The rectifier that converts the DC supply to AC is set for 110 volts 60 Hertz. This system provided good isolation from spikes and provides battery backup for short term losses of power. Failure of the 6.5kva unit required that the R/V Balkash use the 3.5 kva UPS. The total power requirements for the equipment onboard the R/V Balkash exceeded the capacity of the UPS system. It was necessary to used the 6.8 Kva diesel-powered generator, several 220/110 1500 watt transformers, and the ship's 220/50hz power to meet the power requirements.

The R/V Titov's acquisition lab used ship's 220vac 50hz power combined with 220/110 vac,1500 watt transformers. Because of the R/V Titov's small physical size a backup 7.5 kva generator could not be utilized. This would cause problems late in the expedition due to the failure of the main ship's generator near the end of the expedition.

5. Ocean Bottom Seismometers

The Ocean Bottom Seismometer (OBS) is a self-contained data-acquisition system that is deployed on the ocean floor to record long range seismic data on a 200 Megabyte disk. The basic components of this systems are illustrated in Figure 6. The US Geological Survey OBS has been designed as a continuous recording system setup to acquire signals from one vertical 4.5 Hertz geophone, two horizontal 4.5 Hertz geophones, and one hydrophone. The software controlling the system can select any combination of these four channels to sample at 200 samples/second, providing a record time of 36 hours for all four channels. Once during each acquisition of data into the memory buffer (1,015,808 bytes), the system will record the time of the sample. The time and the data pointer for that time are recorded into a header that gets recorded with each memory buffer of data. There are eight OBS's. Four are rated for a depth of up to 500 meters, and the other four OBS's are rated to 5,000 meters. Each OBS is powered using 72 alkaline batteries which will power all of the systems for seven days.

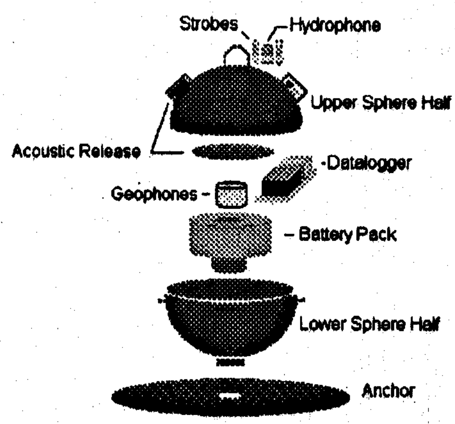

Figure 6. Major Components of the OBS

The OBS's record data continuously and have time-of-day marks in the data as the only reference to external events. To provide the highest possible accuracy, time is recorded to the nearest millisecond. Each OBS uses an oven-controlled oscillator as a stable clock reference, for which the drift in time can be as little as 1 millisecond/day. The time-of-day is set via software in each logger using the minute pulse of the GPS satellite clock as a starting trigger. When locked on a satellite, the time is accurate to within 100 nanoseconds. The offset from GPS time is determined by comparing the second pulse of the data logger with the second pulse of the GPS clock. After each deployment, the offset is measured again to determine the total drift.

The dataloggers in each OBS use a 200 Megabyte hard disk to store the acquired data. The data must be transferred to another storage media each time an OBS is retrieved. A 386 PC with 2.2 gigabytes of hard disk and an Exabyte tape drive is used to archive the data. Data is downloaded from the data logger onto the hard disk. The quality of the data is checked, and once all of the OBS's have been downloaded, the data files are written to Exabyte tape for permanent storage.

Deployment and recovery operations are simple operations designed to work on a variety of different vessels. The OBS's are programmed, sealed, and stored on deck prior to deployment. A Magellan GPS navigation system is used to steer the ship to the deployment site. There is no logging of navigation data except for writing down the location when the OBS is deployed. This position is used later to locate the OBS for retrieval and is used in the data analysis to determine the distance offset to the shooting ship. When ready to deploy, the acoustic release is tested a final time, and the OBS is then attached to its anchor. A block and tackle is used to lift the OBS and anchor, swing the assembly outboard of the ship, and then lowered to the water surface. A simple rope loop and metal pin is used to release the OBS into the water, and the assembly freefalls to the bottom. An acoustic release is used to free the OBS from its anchor. At the surface, two externally mounted strobes will flash to aid in spotting the floating OBS.

Cruise Summary:

The technical coordination and cooperation between USGS/AMG and the Southern Institute of Oceanology and Alek Bardardinov, Institute of Limnology, Irkutsk made this expedition on Lake Baikal a great accomplishment. To date this is the most comprehensive and qualitative marine seismic survey of this region. Over 1800km of high quality seismic reflection data and over 500km of OBS refraction data was recorded during this period.

Communications between ships was a great obstacle during this expedition. The Russian supplied high-frequency(HF) radios were not adequate over the long distances worked on the Lake. USGS supplied VHF radios, which were basically line of sight, could not provide communications when the ships were more than 30 km apart. It is suggested that any further expeditions to this region would warrant the use of a satellite communications system. When ships are working approximately 250 kilometers apart much of the time, which was required when shooting OBS lines, these communication tools are a necessity.

This was the largest MCS/OBS program that USGS has undertaken. By working closely with our Russian colleagues, we have learned through the lessons which Lake Baikal has thought us that nothing is impossible with trust, hard work, and a little time off for good behavior!

Acknowledgments:

The success of this expedition was due mainly to the hard work and co-operation of the personnel listed in Appendix 6. Over three years of effort at Gelendzhik and Woods Hole culminated with this two month expedition on Lake Baikal. We would like to thank the many people who contributed their time and expertise to the premobilization of the equipment and supplies necessary to this expedition. Many thanks are due to the local people of Listvyanka for their support in providing machinery, expertise, and time in helping with the mobilization and de-mobilization of the two Research Vessels. A special thanks to our "volunteer" colleague Mr. Marc Behrendt for his tireless effort with communications and interpretation. Mr. Brian Heath, Contracting Officer, Reston Virginia, is to be congratulated for his extra-ordinary effort in pushing through the contracts for our heavy machinery lease. As stated earlier, there are too many special thanks to be given here but congratulations to all for this exceptional team effort in cooperation and coordination. Although most days were spent working on the lake and in port, we did find out that our Russian colleagues take their volley-ball as serious as their jobs. We would like to thank them for some spirited games at the "SANITORIUM" courts. Final analysis has us tied on all rounds. We feel a rematch is in order! Thanks to Ms. Judi Allen, PMG, for her 6 months of preparation and 3 months of work on the ships. You will never know how much difference you made in this endeavor.

Appendix 1 thru 5 - Not available.

Appendix 6 Cruise Personnel

R/V Balkash

Captain: Yuri Gorbunov
Chief Engineer: Nikolai Vaskovskiy
Co-Chief Scientists:
- Alexander Ja.Golmshtok, Institute Oceanology, Gelendzhik,Russia
- Kim D.Klitgord, U.S.Geological Survey, Woods Hole,Ma.
- Christopher A. Scholz, Duke Univ.Marine Lab, Beaufort, N.C.

Chief of Operations:
- Leonid Akentiev, Institute of Oceanology, Gelendzhik,Russia
- David Nichols, U.S. Geological Survey, Woods Hole,Ma. USA

Scientific Party:
- Judith Allen, USGS/PMG, Menlo Park, Ca.
- Ivan Beliyev, Institute of Oceanology, Moscow, Russia
- Yegor Czerniawski, Institute of Oceanology, Moscow, Russia
- Alexander Elinkov, Institute of Oceanology, Gelendzhik, Russia
- David Foster, USGS/AMG, Woods Hole, Ma.
- Valedi Gorjunov, Concern Ros Oil and Gas, Kransdor, Russia*
- Sergi Hanukayev, Institute of Oceanology, Gelendzhik, Russia
- Eugene Konyev, Institute of Oceanology, Gelendzhik, Russia
- Sergei Kraskovsky, Institute of Oceanology, Gelendzhik, Russia
- Jim McGill, Duke University, Beaufort, N.C.
- Alexander Pisetsky, Institute of Oceanology, Gelendzhik, Russia
- Christopher Schneider, USGS/AMG, Woods Hole, MA
- Victor Trofimenko, Institute of Oceanology, Gelendzhik, Russia*
- Alexander Tupkin, Concern Ros Oil and Gas, Kransdor, Russia
- Derek Unger, USGS/AMG, Woods Hole, Ma.
- Hal Williams, USGS/PMG, Menlo Park, Ca.
- Nikita Yazichyen, Institute of Oceanology, Gelendzhik, Russia
- Anatoly Zinoviev, Institute of Oceanology, Gelendzhik, Russia

R/V Titov

Captain: Alexander Sakhalov
Chief Engineer: Victor Platonov
Chief Scientist:
- Uri ten Brink, U.S.Geological Survey, Woods Hole,Ma.

Scientific Party:
- Greg Miller, USGS/AMG, Woods Hole, MA
- Marc Behrendt, San Fransico, CA.
- Dwight Coleman, USGS/AMG, Woods Hole, MA
- Alik Badardinov, Limnological Institute of the Siberian Branch of the Russian Academy of Science, Listvyanka, Russia